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Perceptions of climate-related risk among water sector professionals in Africa—Insights from the 2016 African Water Association Congress

Connolly Katherine[a], Mwaura Mbutu[b], Bartram Jamie[a,c], Fuente David[d,*]

[a] The Water Institute at the University of North Carolina, Chapel Hill, United States
[b] Nairobi City Water and Sewer Company, Ltd., Kenya
[c] Department of Environmental Sciences and Engineering, Gillings School of Global Public Health, the University of North Carolina, Chapel Hill, United States
[d] School of Earth, Ocean & Environment, University of South Carolina, United States

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ABSTRACT

The ability of water and wastewater utilities to provide safe and reliable water and sanitation services now and in the future will be determined, in part, by their resilience to climate change. Investment in infrastructure, planning, and operational practices that increase resilience are affected, in turn, by how water sector professionals perceive the risks posed to utilities by climate change and its related impacts. We surveyed water sector professionals at the 2016 African Water Association's Congress in Nairobi, Kenya to assess their perceptions of climate-specific and general risks that may disrupt utility service. We find that water sector professionals are most concerned about climate-specific and general risks that affect utility water supplies (quantity), followed by adequacy of utility infrastructure. We also find that professionals tend to rank climate-specific risks as less concerning than general risks facing utilities. Furthermore, non-utility professionals are more concerned about climate-specific risks and climate change in general than utility professionals. These findings highlight the multiple, competing risks utilities face and the need for adaptation strategies that simultaneously address climate-specific and general concerns of utilities.

1. Introduction

Throughout the 21st Century, climate change is expected to affect water availability and quality worldwide (Jimenez et al., 2014). The impacts are predicted to be particularly severe in places that face water scarcity, such as many regions throughout Africa (Jimenez et al., 2014; Niang et al., 2014). Much of Africa has experienced warming over the past century and this is expected to continue, affecting the hydrological cycle and water demand across the sub-continent (Niang et al., 2014; Serdeczny et al. 2016). Forecasters predict that northern and southwestern Africa are likely to see an overall decrease in precipitation over the next century, while eastern and central Africa may experience an increase in precipitation (Niang et al., 2014). Furthermore, a number of climate models predict an overall increase in risk of both extreme temperature and precipitation events (Jimenez et al., 2014; Niang et al., 2014). The ability of water and wastewater utilities to advance the Sustainable Development Goal of ensuring universal access to safe and affordable water and sanitation services will be determined, in part, by the extent to which they are resilient to climate change.

Risk perception influences behavior, specifically in the context of climate change adaptation and mitigation (Kettle and Dow, 2014; O'Connor et al., 2005, 1999a; Semenza et al., 2008). For utility managers to adapt to climate change, they must be aware of it and perceive risk associated with it (Brettle et al., 2015; Moser and Luers, 2007). However, little is known about water and wastewater utility professionals' perceptions of climate-related risks or how utilities view the various risks they face in relation to one another. A small number of studies have quantitatively examined water and wastewater utility professionals' perceptions of weather and climate extremes, but none have focused on Africa specifically (Bolson et al., 2013; Brettle et al., 2015; Carter and Morehouse, 2003; Dow et al., 2007; Economist Intelligence Unit, 2012; Ekstrom et al., 2017; Finucane et al., 2013; O'Connor et al., 2005, 1999b; Rajbhandary et al., 2010). To our knowledge, studies in the literature have also not compared the climate change risk perceptions of utility professionals to those of other professionals in the water sector.

This study examines the perceptions of water sector professionals in Africa toward climate-specific and general risks facing water and wastewater utilities. We report the results of a survey of participants at the bi-annual Congress of the African Water Association (AfWA), a professional organization composed of water sector professionals throughout Africa (AfWA, 2015). The survey assessed perceptions of

* Corresponding author.
E-mail addresses: katieg.connolly@gmail.com (K. Connolly), MMbutu@nairobiwater.co.ke (M. Mbutu), jbartram@email.unc.edu (J. Bartram), fuente@seoe.sc.edu (D. Fuente).

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the likelihood and severity of risks that have the potential to disrupt utility water and/or wastewater services in order to answer two related questions: 1) how do water sector professionals perceive general and climate-specific risks, and 2) how do the risk perceptions of utility professionals compare to those of other professionals in the water sector? The results of the survey indicate that water sector professionals are most concerned about risks associated with utilities' ability to provide adequate quantities of water to their customers and that non-utility professionals tend to be more worried about climate change and climate-specific risks than professionals who work for a water or wastewater utility. This paper details these results and discusses possible implications for the climate change adaptation process among utilities in the region.

2. Materials and methods

2.1. Survey design and implementation

This study defines risk in terms of both probability and severity. Probability refers to "the likelihood of some specific negative event [occurring] as a result of exposure to a hazard"; and severity, or risk effect, is "the extent of detriment associated with [an] adverse event" (Breakwell, 2010, p. 857). Risk perception is the way in which an individual judges risk (Slovic, 1987).

Risks most relevant to utilities, particularly those in Africa, were identified through a review of the literature on water utility performance and climate change. In particular, risks were identified by reviewing over 100 case studies from utilities around the world facing risks related to climate and weather. Case studies were drawn from a variety of sources, including from The World Bank (Danilenko et al., 2010), the U.S. Environmental Protection Agency (U.S. EPA, 2015), and the Overseas Development Institute (Oates et al., 2014). The case studies were analyzed and common risks were identified, including both climate and weather-related risks (e.g., drought, flooding, etc.) and general risks (e.g., revenue- and infrastructure-related risks). The list of risks included in the survey were reviewed and revised by subject matter experts at the authors' institutions, the national water regulator in Kenya (WASREB), and staff at the Nairobi City Water and Sewer Company who served as the hosts and technical liaisons for the AfWA Congress. This process yielded 20 common risks facing utilities in Africa (Table 1).

The 20 risks identified through the process described above were then assigned to one of two categories of risk: climate-specific risks and general risks. Climate-specific risks, such as drought and flooding, are climate and/or weather events that have the potential to disrupt utility service. General risks are all other risks that may disrupt utility service (e.g., increased water demand, insufficient revenues for operations and maintenance, non-revenue water loss, etc.) that are not solely attributable to climatic events. These general risks may be related to, or influenced by, climate-specific risks, but are not exclusively associated with climate or weather events. For example, increased water demand may be driven by population growth, increased economic growth, increased temperature, or some combination of these and other factors. The 20 risks used in the survey include eight climate-specific risks and 12 general risks (Table 1).

This study aimed to capture the perceptions of both those who directly work for water and wastewater utilities (utility professionals) and those of professionals in the broader water sector (non-utility professionals working for regulatory agencies, donor agencies, government agencies, etc.) towards these climate-specific and general risks. To distinguish between these two groups, survey respondents were asked to select the type of organization that most accurately described their organization from a list of 13 different options (including "Other" and "I prefer not to answer"). Respondents who selected an option other than water or wastewater utility were categorized as non-utility respondents.

Two different versions of the survey were used to assess the perceptions of the respective groups. All utility and non-utility respondents answered questions regarding the type and location of the organization they work for, their position within their organization, and overall concern about climate change. Both groups of respondents were also asked to rate the likelihood and severity of the 20 selected risks. However, utility respondents were asked about their perceptions of risk regarding the utility they work for, whereas non-utility respondents were asked about their perceptions of risk regarding the utility or utilities in the region(s) where their organization operates. In addition to the 20 selected risks, respondents were also given the opportunity to report and assess other risks not explicitly included in the risk choice set.

Following Dow et al. (2007), respondents were asked to assess each risk over a ten-year planning horizon. While a multi-decadal or century-long timeframe is often used when considering climatic changes, a ten-year planning horizon was used because it is more decision-relevant for utility managers.

The survey was administered to participants in the 2016 AfWA Congress, which draws water sector professionals from across the continent. In particular, during the February 2016 AfWA Congress in Nairobi, Kenya, the survey was emailed (via Qualtrics) to attendees who provided an email address when registering for the Congress (n = 807). The survey was also advertised in plenary sessions during the Congress and on fliers distributed during presentation sessions held at the Congress to encourage participants to complete the survey and invite participation from those who had not provided an email address at registration. The survey was formatted to be taken on a computer, tablet or smartphone and respondents had the option of taking the survey in English or French. Congress attendees were initially contacted at the beginning of the Congress and those who had not completed the survey received four reminder emails. Late registrants for the Congress (n = 228 out of total 807) were initially emailed on the second day of the Congress and received two reminder emails. The University of North Carolina's Internal Review Board approved the research prior to implementation of the survey (study #16-0389) and each respondent was required to provide informed consent. Survey responses were collected February 22nd through March 5th, 2016.

2.2. Analytical approach

Perceived likelihood and severity were measured on a continuous scale from 0 = not at all likely/severe to 100 = extremely likely/severe (Patt and Schröter, 2008); these two dimensions were used to construct a measure of risk perception. Risk perception was calculated as the product of perceived likelihood and severity (de Zwart et al., 2007; Griffin et al., 2008; Yang, 2016). An individuals' risk perception toward risk C is defined as described in Eq. (1).

Table 1
Risks included in the survey.

Climate-specific risks	High temperatures for several months; extremely high temperatures for several days or weeks (i.e., heat wave); low temperatures for several weeks; drought; flooding; sea level rise; cyclones; increased precipitation that does not result in flooding;
General risks	Water scarcity; decreased source water quality; increased demand for water; increased costs of electricity; increased labor costs; high levels of non-revenue water; aging infrastructure; inadequate capital funding; insufficient revenues for operations and maintenance; personnel turnover; lack of qualified staff; vandalism

$$PR_i^C = \frac{Likelihood_i^C \times Severity_i^C}{100} \quad (1)$$

Where PR_i^C is the measure of individual i's perceived risk associated with risk C, $Likelihood_i^C$ is individual i's perception of risk C occurring in the next 10-years, and $Severity_i^C$ is individual i's perception of the severity of the impact associated with risk C conditional on it occurring in the next 10 years.

Aggregate measures of respondents' mean risk perceptions towards climate-specific and general risks were constructed by averaging the risk perception values across the eight climate-specific and 12 general risks, respectively. Sensitivity analysis was conducted on the risks included in the aggregate measure of climate-specific risks. Additionally, to capture water sector professionals' overall level of concern about the effect of climate change on utilities' ability to provide high quality water and sanitation services, respondents were asked to indicate how concerned they were about climate change disrupting utility service over the next ten years (from 0 = not concerned to 100 = extremely concerned). This provided an opportunity to gauge respondents' overall concern about climate change and assess construct validity associated with the climate-specific risk perceptions. All data analysis was completed using Stata statistical software (StataCorp, 2015).

3. Results

One hundred and forty-nine individuals (18% of participants emailed) started the survey and 90 individuals (11% of participants emailed) completed the entire survey. The results presented below include information from the 90 respondents who completed the survey. Overall, water sector professionals who attended the AfWA Congress were most concerned about the impacts of drought, increased water demand, and water scarcity on utilities. Respondents also expressed concern about the adequacy of utilities' infrastructure stock. Overall, respondents expressed lower mean risk perceptions towards climate-specific risks than general risks. However, respondents tended to rate their general concern for the impact of climate change on utilities closer to 'extremely concerned' than 'not at all concerned.' Finally, non-utility professionals perceived greater risk from the impacts of climate-specific risks on utilities than utility professionals.

3.1. Respondent characteristics

The proportions of respondents that work for a utility (48%) and for an organization other than a utility (52%) were nearly equal (Table 2). The majority of utility respondents (67% of utility respondents) worked for a utility that provided both water and wastewater services. Most respondents (78%) worked in one or more countries in Africa and more than half of all respondents (56%) worked in Kenya, where the AfWA Congress was held.

Table 2
Survey respondent characteristics.

Respondent Characteristic	No. of Respondents	Percent of Respondents
Utility professional	43	48%
Water only	*14*	*16%*
Wastewater only	*0*	*0%*
Both	*29*	*32%*
Non-utility respondents	47	52%
Government agency	9	10%
University/think tank	7	8%
NGO	6	7%
International donor organization	6	7%
Consulting firm	5	6%
Regulatory agency	4	4%
Other	11	12%
Location where respondent works		
Africa (*Kenya*)	70 (*50*)	78% (*56%*)
Other region	6	7%
Unspecified	14	15%

3.2. Perceived likelihood and severity

Respondents perceived increased demand to be the risk most likely to disrupt or interfere with utility service over the next ten years (μ = 68, σ = 33), followed by drought (μ = 66, σ = 34) and inadequate capital funding (μ = 62, σ = 33) (Fig. 1). Respondents perceived cyclones to be the least likely risk to disrupt or interfere with utility service (μ = 12, σ = 25) and low temperatures for several weeks and sea level rise were perceived as second and third least likely, respectively (μ = 17, σ = 29; μ = 21, σ = 33).

With respect to perceived severity, respondents perceived drought to have the most severe consequences for utility service provision (μ = 61, σ = 35) over the next ten years, followed by water scarcity (μ = 60, σ = 37) and increased demand (μ = 58, σ = 33) (Fig. 1). The three risks with the lowest perceived likelihood also had the lowest perceived severity: cyclones (μ = 15, σ = 26), low temperatures for several weeks (μ = 17, σ = 27), and sea level rise (μ = 19, σ = 28). Overall, respondents tended to rate risks as more likely than severe (i.e., higher mean perceived likelihood than perceived mean severity). However, cyclones, low temperatures for several weeks, lack of qualified staff and high temperatures for several months all had higher mean perceived severity than likelihood values.

3.3. Perceived risk

Survey respondents had the highest mean risk perception toward drought (μ = 47.5, σ = 36) (Fig. 2). The risk with the second-highest risk perception value was increased water demand (μ = 44.3, σ = 34.8), followed by water scarcity (μ = 43.9, σ = 36.6). Aging infrastructure (μ = 40.4, σ = 34.5) and inadequate capital funding (μ = 40.4, σ = 34.5) also had relatively high risk perception values. Consistent with perceived likelihood and severity rankings, survey respondents had the lowest mean risk perception toward low temperatures for several weeks (μ = 5.9, σ = 15.8), cyclones (μ = 6.2, σ = 16.9), and sea level rise (μ = 11.3, σ = 22.9). Of the ten factors with the highest risk perception values, only two (drought and flooding) were climate-specific risks. In contrast, four of the five factors with the lowest mean risk perception scores were climate-specific risks.

Mean risk perception across all climate-specific risks was 21.3 (σ = 19.5) out of a maximum of 100. Risks included in the aggregate measure of mean climate-specific risk perception had a scale reliability coefficient (Cronbach's alpha value) of 0.87, indicating that the climate-specific risks combined to create this measure have high internal consistency and are thereby likely to measure the same concept (O'Connor et al. 1999a). Respondents' mean risk perception toward all general risks was 33.8 (σ = 26.2) out of a possible 100 points (Cronbach's alpha = 0.94, demonstrating high internal consistency). Respondents' mean risk perception toward general risk factors was significantly higher than mean risk perception toward climate-specific factors (33.8 vs. 21.3, $t(178) = 3.64$, $p < 0.001$, see Fig. 3).

Not all countries, or utilities within countries, represented in this survey face the risk of cyclones, sea level rise, or low temperatures. Thus, sensitivity analysis was conducted on the measure of mean climate-specific risk perception. In particular, mean climate-specific risk perception was calculated by removing low temperatures for several weeks, cyclones, and sea-level rise in sequence from lowest perceived risk to highest (Table 3). When low temperatures for several weeks was removed from the mean climate-specific risk perception calculation, the mean across the seven remaining climate-specific risks increased to 23.5 (σ = 19.5) and there was a statistically significant difference between this value and mean risk perception toward general risks ($t(178) = 2.918$ $p < 0.01$). When low temperatures and cyclones were

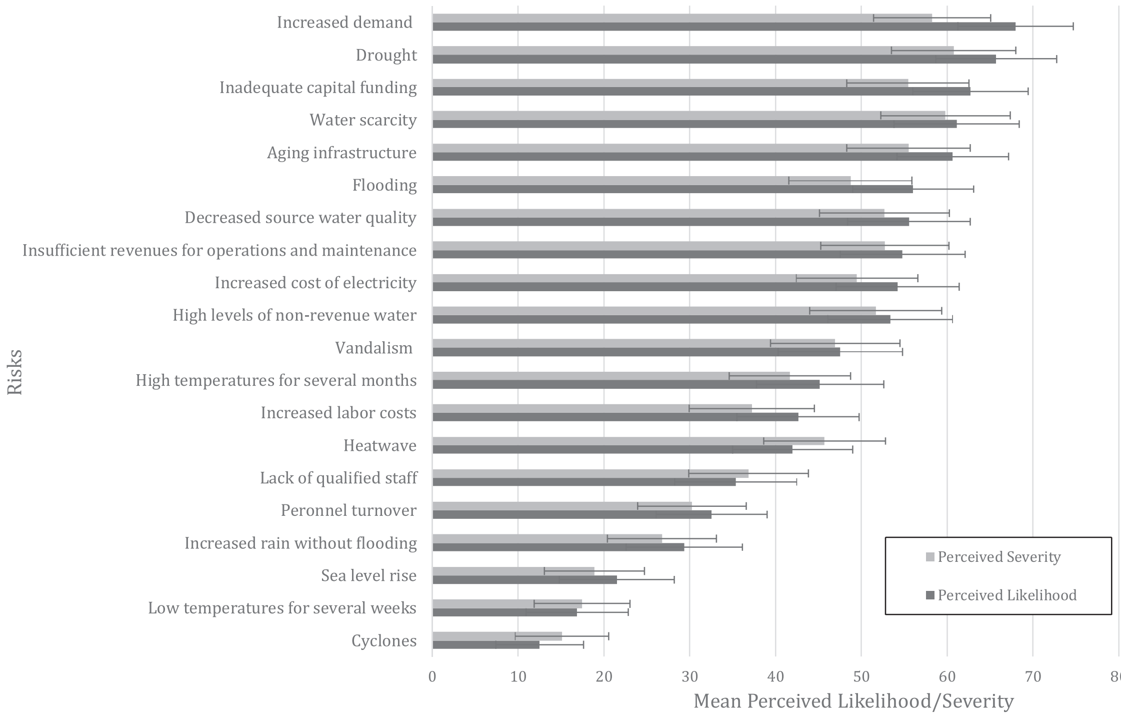

Fig. 1. Mean perceived likelihood and severity toward all risks included in the survey. Error bars represent the 95% confidence intervals.

both excluded from the mean climate-specific risk perception value, the difference between this mean ($\mu = 26.4$, $\sigma = 22.8$) and mean risk perception toward general risks remained significant ($t(178) = 2.918$ $p < 0.01$). When sea level rise was removed, the mean across the five remaining climate-specific risks was $\mu = 29.6$ ($\sigma = 24.7$) and there was no longer a statistically significant difference from mean risk perception toward general risks ($t(178) = 1.11$ $p < 0.50$).

The mean value for respondents' overall concern about the impact of climate change on utilities' ability to provide water and sanitation services was 75.7 ($\sigma = 23.4$) out of 100, indicating that respondents were more likely to be "extremely" concerned about climate change, as opposed to "not at all" concerned.

3.4. Risk perceptions of utility and Non-utility respondents

Non-utility respondents reported higher perceptions of risk toward each climate-specific risk than the utility respondents (Fig. 4). Additionally, mean risk perception across all climate-specific risks was significantly higher among non-utility respondents than utility respondents (26.4 vs. 15.7, $t(88) = 2.69$, $p < 0.01$). A sensitivity

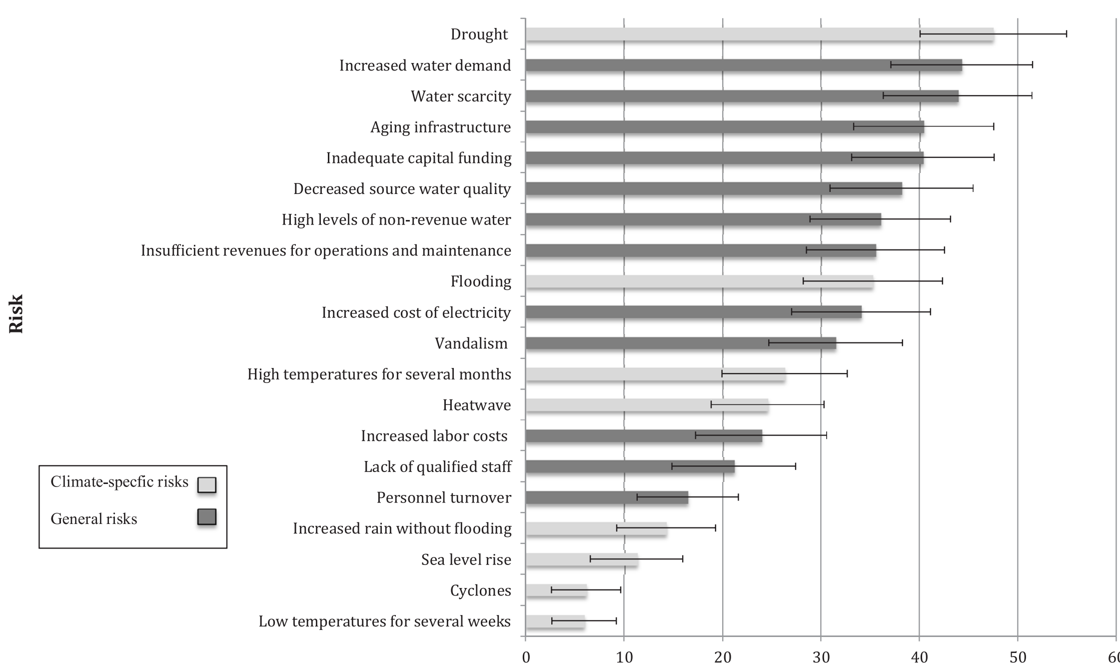

Fig. 2. Comparison of water sector professionals' risk perceptions toward climate-specific and general risks. Error bars represent the 95% confidence intervals.

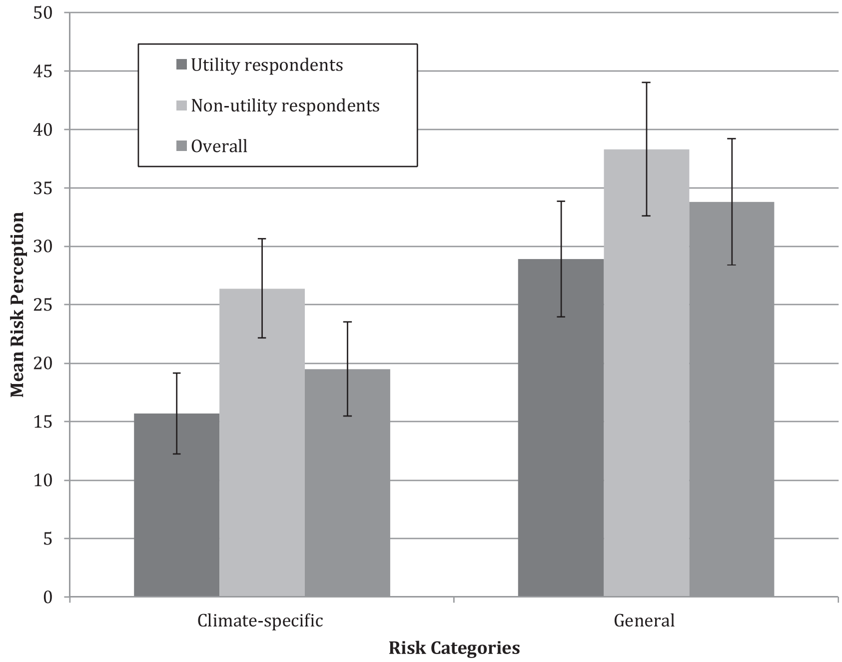

Fig. 3. Mean risk perception toward climate-specific and general risks across utility, non-utility and all respondent categories. Error bars represent the 95% confidence intervals.

analysis was conducted for utility and non-utility mean climate-specific risk perceptions and the difference in means remained significant when low temperatures for several weeks, cyclones and sea level rise were excluded (see Appendix A for details). Non-utility professionals also had higher overall concern about climate change compared to utility professionals. In particular, mean concern about the general impact of climate change on utilities among non-utility respondents ($\mu = 80.3$, $\sigma = 19.3$) was greater than that of utility respondents ($\mu = 70.6$, $\sigma = 26.6$; $t(88) = 2$, $p < 0.05$). Overall, we find a statistically significant ten to eleven-point difference between the means for both general climate change concern and mean climate-specific risk perception among utility and non-utility respondents. Non-utility respondents reported higher perceived risk toward general risks ($\mu = 38.3$, $\sigma = 27.6$), compared to utility respondents ($\mu = 28.9$, $\sigma = 23$) as well. However, the difference is not statistically significant ($t(88) = 1.71$ $p < 0.1$).

4. Disscussion

Our findings suggest that AfWA Congress participants were most concerned about risks related to adequate water supply (e.g., increasing water demand, drought, and water scarcity) and risks associated with the adequacy of utility infrastructure (e.g., capital funding and ageing infrastructure). On average, respondents ranked climate-specific risks as less concerning than general risks facing utilities. However, respondents did express relatively high overall concern about the impact of climate change on utilities. Furthermore, non-utility professionals had higher levels of perceived risk toward climate-specific risks and greater concern over the general impacts of climate change on utilities compared to utility professionals.

4.1. *Perceptions of climate-specific and general risks*

Respondents to our survey had the highest perceived risk toward factors that affect utilities' ability to provide sufficient quantities of water to their customers. In particular, respondents were most concerned about drought, increased water demand, and water scarcity. Respondents also reported relatively high perceived risk towards aging infrastructure, inadequate capital funding, high levels of non-revenue water and insufficient revenue to cover utilities operating expenses. This is consistent with other studies that find increased demand, infrastructure problems, and capital funding to be important risks facing utilities (Arnell and Delaney, 2006; Carter and Morehouse, 2003; Economist Intelligence Unit, 2012; Stroup, 2011; Subak, 2000). As noted above, of the ten factors with the highest risk perception values, only two (drought and flooding) were climate-specific risks. This

Table 3
Sensitivity analysis of aggregate climate-specific risk perceptions.

Aggregate measure of climate specific risk (n = no. of risks)	Climate-specific risks included in measure of aggregate climate-specific risk								
	Drought	Flooding	High temp. (several mo.)	Heat-wave	Increased rain (no flooding)	Sea level rise	Cyclones	Low temp.	Mean *(s.d.)*
Aggregate climate-specific risk Base case (n = 8)	X	X	X	X	X	X	X	X	21.3[c] *(19.5)*
Aggregate climate-specific risk (n = 7)	X	X	X	X	X	X	X		23.5[b] *(21)*
Aggregate climate-specific risk (n = 6)	X	X	X	X	X	X			26.4[a] *(22.8)*
Aggregate climate-specific risk (n = 5)	X	X	X	X	X				29.6 *(24.7)*

[a] Mean is different the mean general risk at the 0.05 level of significance.
[b] Mean is different the mean general risk at the 0.01 level of significance.
[c] Mean is different from the mean general risk at the 0.001 level of significance.

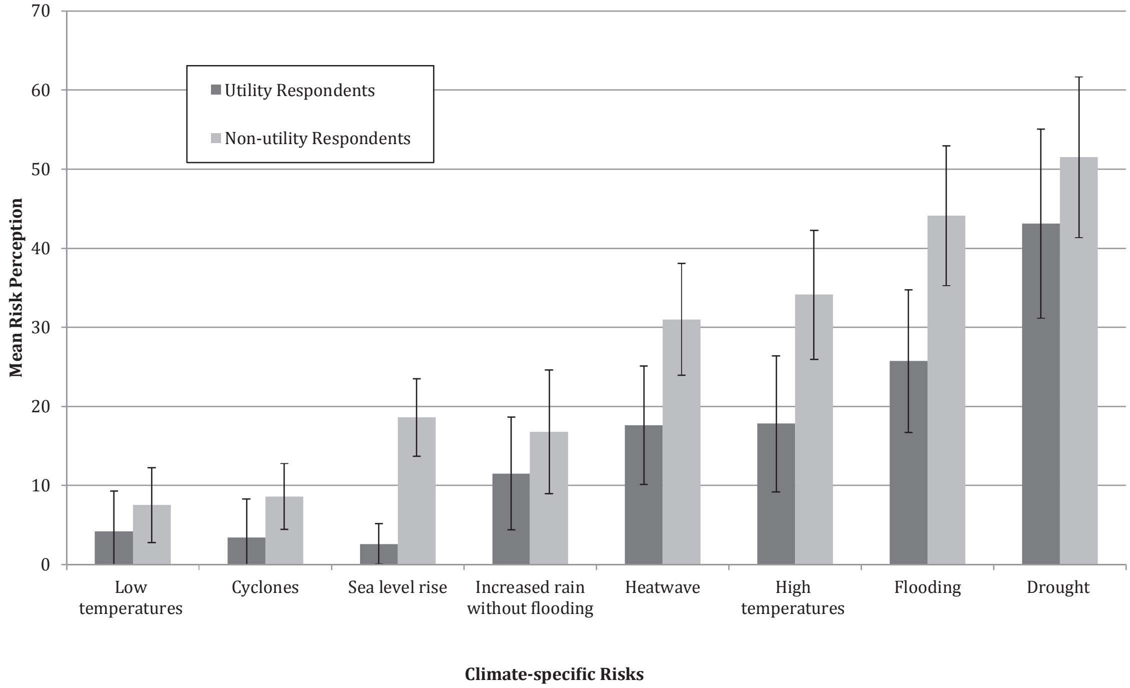

Fig. 4. Mean risk perception toward climate-specific factors among utility and non-utility professionals. Error bars represent the 95% confidence intervals.

suggests that risks and challenges posed by climate change must be viewed in the broader portfolio of risks facing utilities.

Overall, respondents were less concerned about climate-specific risks than general risks facing utilities. Sensitivity analysis indicates that this finding is generally robust to the risks included in the aggregate measure of climate-specific risk. This finding is consistent with previous studies in other regions. For example, utility professionals in England and Wales (Arnell and Delaney, 2006) and Florida (Rajbhandary et al., 2010) expressed greater concern over non-climate or weather impacts on their systems, such as increased demand, population growth and inefficient water use by customers, compared to risks associated specifically with climate change or weather events.

Our findings may reflect the fact that participants in the AfWA Congress were more concerned about current, non-climate risks facing utilities over a ten-year period than the risks posed by climate change, which may be perceived to be temporally distant. It is possible that respondents did not view climate-specific risks as a threat within the ten-year timeframe considered in the survey; past research on climate change risk perceptions has found that individuals often view climate change as a psychologically distance risk (Leiserowitz, 2006; McDonald et al., 2015). This means that people often perceive climate change as a risk that will predominantly affect future generations (temporally distant) and other places (geographically distant). Therefore, the relatively low concern with respect to climate-specific risks observed in our sample may reflect the fact that respondents did not anticipate climate change impacts occurring within the next ten years, whereas risks such as increased demand and aging infrastructure are already affecting utility operations.

We caution against interpreting our results as evidence of a stark divide between respondents' perceptions of climate-specific and general risks facing utilities. These two categories of risks are not mutually exclusive. For example, increased water demand, a risk not categorized as climate-specific, may be driven by increases in the service population (e.g., via population growth and rural-urban migration), increased economic growth, increased temperatures, or some combination of these factors. Similarly, water scarcity may reflect increasing demand, drought, or utilities' failure to invest in adequate water supply infrastructure. Thus, while risks like increased demand and water scarcity are not climate-specific risks, they may directly be affected and exacerbated by climate change.

Although participants in the AfWA Congress expressed higher risk perceptions, on average, toward general risks than climate-specific risks, they expressed a relatively high level of concern about the general impacts of climate change on utilities over a ten-year planning horizon. Respondents' mean level of concern about the general impact of climate change on utilities was 76 out of 100, closer to the "extremely concerned" side of the scale. Upon initial inspection, this may seem to contradict our findings related to climate-specific risks facing communities. However, there are several plausible explanations for why respondents expressed a relatively high level of concern about climate change in general but relatively low perceived risk for climate-specific risks facing utilities.

For instance, climate change is widely discussed in the water sector (Danilenko et al., 2010; Miralles-Wilhelm et al., 2017; Oates et al., 2014) and it is possible that respondents have internalized broader discourse in the sector related to the general threat of climate change. However, this broad concern may not translate into concern about individual climate-specific risks. This is consistent with Kuruppu and Livermann (2011) who studied households' perceptions of climate-related risks in Kiribati. They hypothesize that households' greater concern about climate change in general, compared to their concern over specific climate-related threats to water, was due to individuals being overwhelmed by the idea of climate change in the abstract, but feeling that they are better capable of addressing its specific impacts.

It may also be that respondents to the survey perceived climate change in general as an unknown and serious risk, but that the individual risks associated with climate change (e.g., drought and flooding) were more familiar. Risk perception research has found that people tend to be less concerned about risks they are more familiar with, and have higher perceived risk towards risks they view as unfamiliar, unknown or uncontrollable (Slovic, 1987).

Additionally, respondents may have also viewed climate change as a serious risk, but not have had a clear sense of how climate change will impact a particular utility or set of utilities. This may reflect the fact that downscaled projections of temperature, precipitation, and storm events largely do not exist at a resolution that utilities managers can

use, particularly in many African countries. Despite several plausible explanations for the divergence in perspectives observed between the general threat of climate change and climate-specific risks facing utilities, we cannot identify the precise reason for this divergence in our sample and view this as an area for future research.

4.2. Utility vs. non-utility perceptions

Our results highlight significant differences between the perceptions of utility and non-utility respondents. Non-utility respondents had higher mean risk perception toward climate-specific risks and expressed a higher level of concern about the general impact of climate change on utilities than respondents who worked directly for utilities. Previous research has found differences in climate change perceptions between those who directly manage or use a resource and others involved in the same sector. For example, Patt and Schröter (2008) found that farmers in Mozambique perceived climate-related events to be both less likely and less serious than policy makers. Similarly, Hagell and Ribic (2014) found that wildlife managers in the United States perceived less adverse impacts from climate change on wildlife than researchers or administrators.

The difference in risk perception between utility and non-utility professionals observed may be attributable to the fact that utility and other resource managers feel that they have greater control over the impacts of climate change on the resource they manage or use compared to those not directly involved in service provision. Previous research has shown that perceived control influences risk perceptions, with greater perceived control over a risk being associated with lower perceived risk (Slovic, 1987). The divergence in perspectives may also be attributable to the fact that individuals who work directly for utilities (or users, in the case of farmers) operate on different timescales than policy makers, researchers or administrators. Much of a utility professional's time is spent dealing with day-to-day issues while regulators, donors, and infrastructure planners are often focused on longer-term planning horizons (Moser and Luers, 2007).

4.3. Limitations

Survey respondents were drawn from participants in the 2016 AfWA Congress in Nairobi, Kenya. Thus, the sample was not representative of water sector professionals in Africa, or necessarily of AfWA's membership. Nevertheless, this study provides insight into how an important subset of water sector professionals in Africa (i.e., AfWA members) view climate-specific risk in the broader portfolio of risks and challenges they face as well as the differing perspectives of those who work directly for utilities and those who do not. Both issues warrant further investigation at broader (sub-continent or continent) and narrower (country) levels.

The survey collected data on respondent's country, but did not collect other personal data, such as age, gender, or education, which have been linked to risk perception. Such information may have allowed us to explain additional heterogeneity in respondents' perceptions of risk. Furthermore, information about utility size (population served, staff) and type(s) of water source for drinking water utilities could have been helpful in explaining differences in risk perceptions.

Additionally, the measures of aggregate risk used in the study implicitly weight each risk equally. Thus, respondents may have expressed lower perceived risks towards certain risks, such as cyclones, because they did not occur in their region. Though sensitivity analysis was conducted on the risks included in the measures of climate-specific risks, future studies could employ location-specific sets of climate risks based on current projections of climate risk.

Finally, this study also had what may appear to be a low response rate (11%). The response rate for the survey may be attributable to the fact that respondents received the email from an unfamiliar email account or were not accustomed to taking online surveys. The response rate was on the low end of the range (6% to 68%) of a review of email surveys conducted by the RAND Corporation (Schonlau et al., 2002). However, the majority of studies included in this review were conducted in high-income countries and we are not aware of a standard response rate for email surveys in low-income countries or Africa in particular.

5. Conclusion

This study examined the risk perceptions of participants in the 2016 AfWA Congress towards a variety of climate-specific and general risks facing utilities. To our knowledge, this study is the first study to examine the climate change risk perceptions of water sector professionals in Sub-Saharan Africa. Respondents had the highest perceived risk toward factors that affect utilities' ability to provide sufficient quantities of water to their customers (e.g., drought, increased water demand, water scarcity, aging infrastructure and inadequate capital funding). Respondents also had relatively high perceived risk towards the impact of high levels of non-revenue water and inadequate revenue on utility operations. Respondents were, on average, more concerned about the general risks facing utilities than risks posed by climate-specific factors. However, respondents expressed a relatively high level of concern about the impact of climate change on utilities in general. This raises important questions related to how sector professionals view, and plan for, risks associated with climate change.

We also find that professionals who do not work directly for utilities expressed higher levels of perceived risk toward climate-specific risks and greater concern over the general impacts of climate change on utilities compared to utility professionals. This difference in perspectives between those directly responsible for resource management or service delivery and professionals in the sector (policy makers, administrators, etc.) has been observed in other sectors and in other regions. Nevertheless, we see an opportunity to determine whether this divergence persists more broadly in the water and sanitation sector in Africa. If so, it may highlight an important disconnect between utility managers and regulators, policy makers, and international donors that warrants further attention.

Despite global concern about the impact of climate change on water security, our findings highlight that risks posed by climate-change must be viewed in the broader portfolio of risks facing utilities. This is particularly true for utilities in Africa and many other low- and middle-income countries that struggle to provide high quality water and sanitation services to their customers. Our findings thus underscore the complex interaction between social, political, technological and environmental factors that affect utilities' ability to provide high quality water and sanitation services. Our findings also highlight the importance of: 1) mainstreaming efforts to increase utilities' resilience to climate change, and 2) better articulating how efforts to increase resilience address sector professionals' concerns about general and current risks facing utilities. Part of this mainstreaming process should draw upon recent advances in robust decision-making to identify "no-regrets" strategies and investments utilities can implement to both improve service delivery and increase their resilience.

Appendix A

Tables A1 and A2

Table A1
Survey questions used to create the measures used in analysis.

Measure	Question wording
Perceived likelihood of climate/weather events	How LIKELY do you think it is that each of the following weather/climate events will disrupt or interfere with your utility's [with utility]delivery of water or sanitation services [in the region(s) where your organization operates][a] at least once over the next 10 years? Please indicate on the scale below where 0 = not at all likely and 100 = extremely likely
Perceived severity of climate/weather events	How SEVERE would the consequences be for your utility's [for utility] delivery of water or sanitation services [in the region(s) where your organization operates] if each of the following weather/climate events occurred over the next 10 years? Please rate each event on the scale below from 0 = Not at all severe to 100 = Extremely severe
Perceived likelihood non-climate factors	How LIKELY do you think it is that each of the following items will disrupt or interfere with your utility's [with utility] delivery of water or sanitation services [in the region(s) where your organization operates] over the next 10 years? Please indicate on the scale below where 0 = not at all likely and 100 = extremely likely
Perceived severity of non-climate factors	How SEVERE would the consequences be for your utility's [for utility] delivery of water or sanitation services [in the region(s) where your organization operates] if each of the following occurred over the next 10 years? Please rate each item on the scale below from 0 = Not at all severe to 100 = Extremely severe
Perceived risk toward general climate change	How concerned are you about climate change disrupting or interfering with your utility's [with utility] delivery of water or sanitation services [in the region(s) where your organization operates] over the next 10 years? Please indicate on a scale from 0 = Not concerned and 100 = Extremely concerned

[a] Text in brackets indicate change in wording for non-utility respondent version of survey.

Table A2
Sensitivity analysis for utility and non-utility mean climate-specific risk perceptions.

Climate-specific risks excluded from aggregate measure (n = no. risks included)	Utility Mean (s.d.)	Non-utility Mean (s.d.)	T-test compared to mean risk perception across general risks
None (n = 8)	15.73 (16.85)	26.43 (20.48)	$t(88) = 2.69$ $p < 0.01$
Low temperatures for several weeks (n = 7)	17.38 (17.5)	29.13 (22.41)	$t(88) = 2.75$ $p < 0.01$
Low temperatures for several weeks; cyclones (n = 6)	19.71 (18.74)	32.54 (25.32)	$t(88) = 2.76$ $p < 0.01$
Low temperatures for several weeks; cyclones; sea level rise (n = 5)	23.13 (21.7)	35.5 (25.96)	$t(88) = 2.44$ $p < 0.05$

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